

Cloudy and Clear Sky Humidity Distributions Observed by AIRS, Cloudsat and CALIPSO

by

Brian H. Kahn

Joint Institute for Regional Earth System Science and Engineering (JIFRESSE)
University of California - Los Angeles/NASA Jet Propulsion Laboratory

and

Andrew Gettelman (NCAR), Annmarie Eldering (JPL),
Eric J. Fetzer (JPL), and Calvin K. Liang (UCLA)

Atmospheric Infrared Sounder Science Team Meeting
California Institute of Technology
April 15-17th, 2008

Acknowledgments: AIRS and CloudSat science teams at JPL for funding support

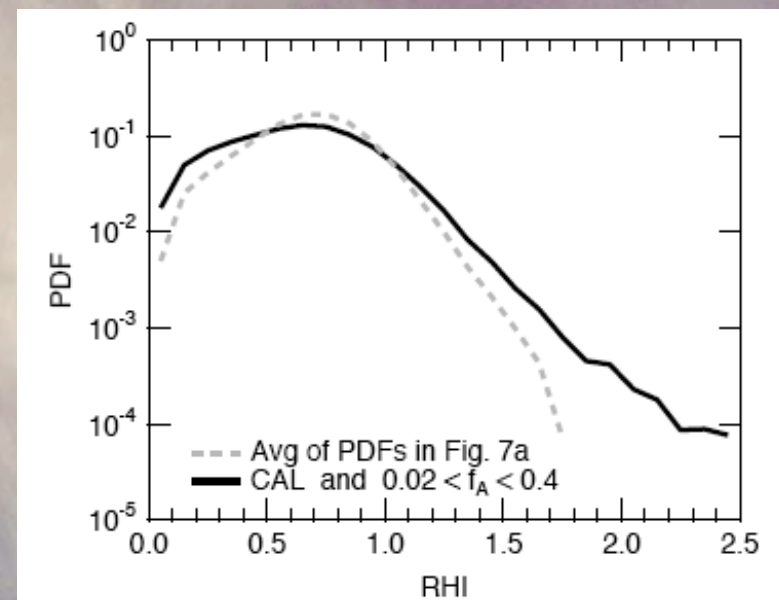
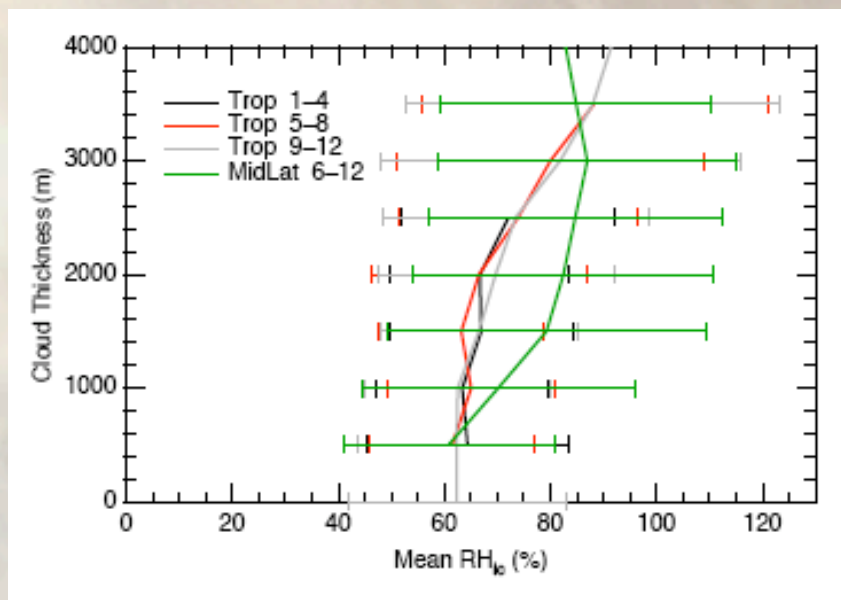
Outline of Talk

- Investigate combinations of A-train observations:
 - (1) AIRS RH profiles & CALIOP + CloudSat cloud structure
 - Seasonality, cloudy/clear sky differences & spatial variations
 - Relationship of RH to radar-derived IWC
 - (2) AIRS T variance and its relationship to RH
 - Does T variance control RH variance?
 - Are aerosol/anthropogenic impacts detectable?
- Current and future research directions

Scientific Motivation

- **Cirrus is an important component of Earth's climate**
 - Climatic mean & variability
 - UT hydrological cycle
 - Direct/indirect forcing, atmospheric heating/cooling & other feedbacks
 - Stratospheric/tropospheric transport & chemistry
- **Recent studies call into doubt understanding of UT cloud evolution & amount**
 - Peter et al. (2006) *Science*
 - Indirect effects poorly characterized [Haag and Kärcher (2004), *JGR*]
 - Retrieval algorithms not consistent [Thomas et al. (2004), *J. Clim.*]
 - Disagreement of cloud properties in climate models [Li et al. (2005), *GRL*]
- **A-Train provides new/improved observations/retrievals of UT**
 - Cirrus optical/microphysical properties (e.g., D_e and τ_{vis}) [Yue et al. (2007), *JAS*]
 - UT RH in clouds/clear sky [Gettelman et al. (2006), *J. Clim.*]
 - Simultaneous observations of microphysics & RH [Kahn et al. (2008), *ACP*]
 - Vertical profiles of cloud structure (radar and lidar)

RHi depends on cloud geometrical thickness + vertical sampling of cloud layer



Cloud thickness definitely matters:
→ Factor 1.4 higher in RH from 0–3 km

Cloud heterogeneity doesn't matter though

Sampling of entire cloud profile broadens RH

Little/no impact in mean RH from vertical sampling biases

Next step: RH within/outside of clouds with CloudSat/CALIOP

- AIRS RH_i
- AIRS T variance
- CloudSat + CALIOP cloud boundaries
- CloudSat IWC
- CloudSat cloud type
- Future combinations: CALIPSO OD, IWC; CloudSat D_e; others

Inter-hemispheric differences in UT RHI

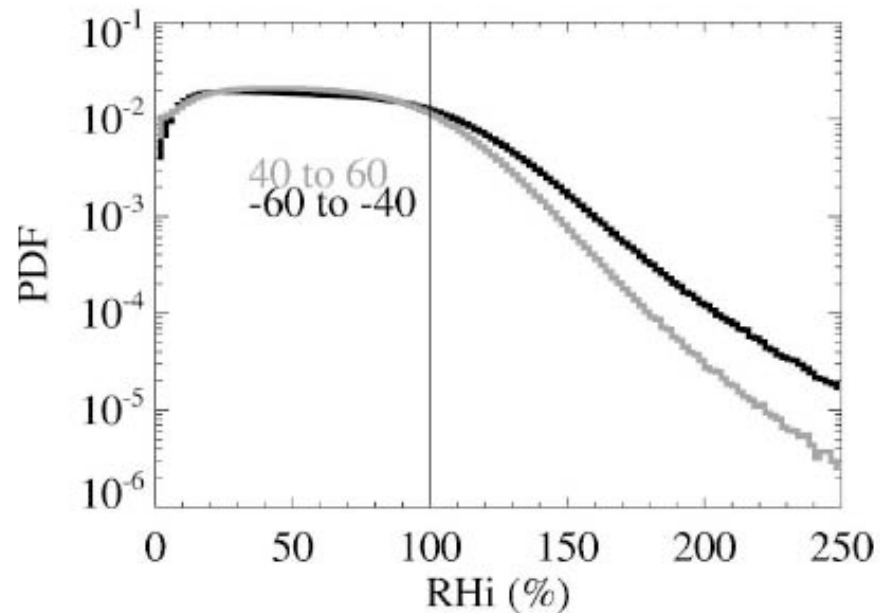
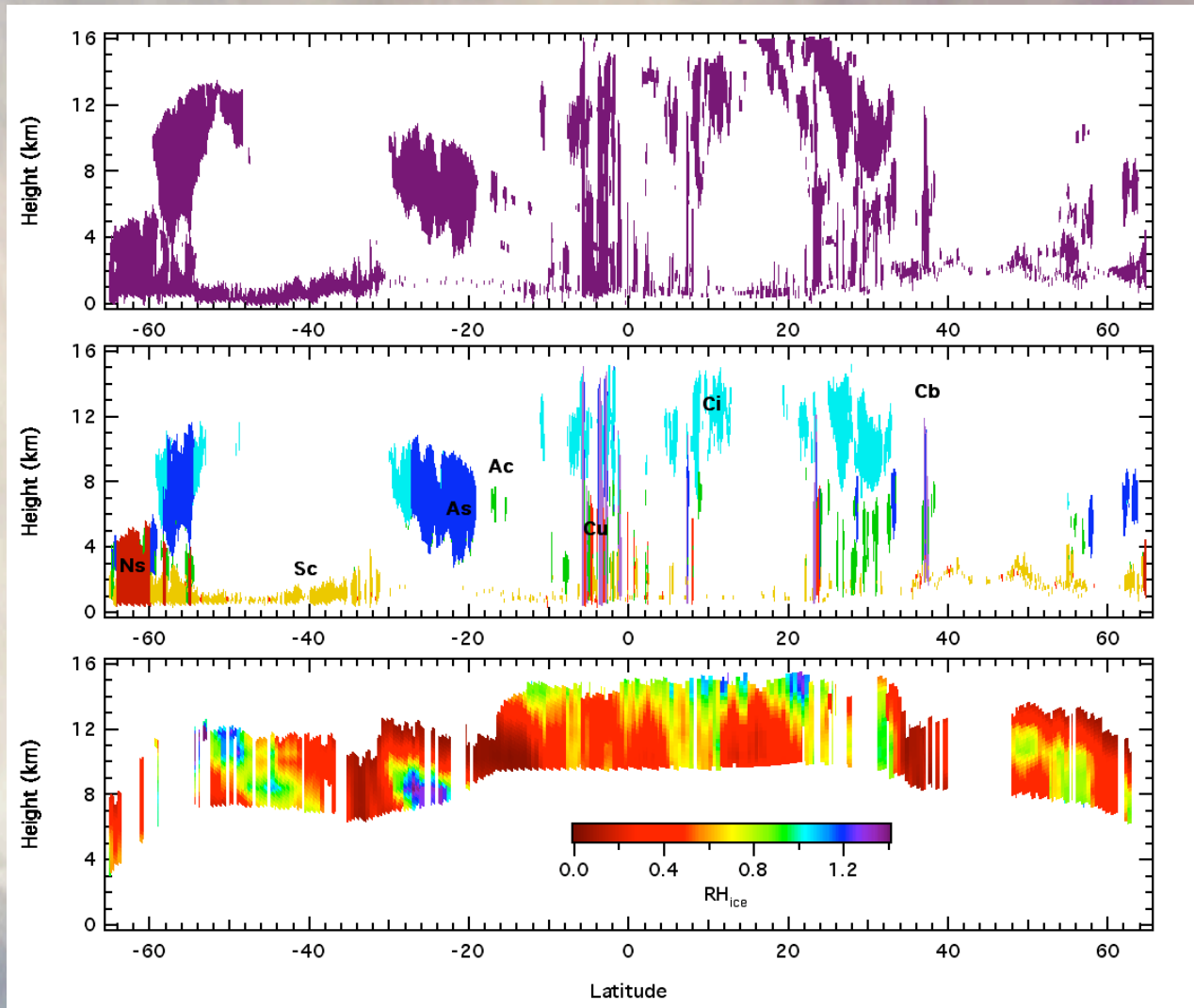


FIG. 12. PDFs of RH from AIRS in the upper troposphere (400–200 hPa) in the midlatitudes of the Southern (black) and Northern (gray) Hemispheres.

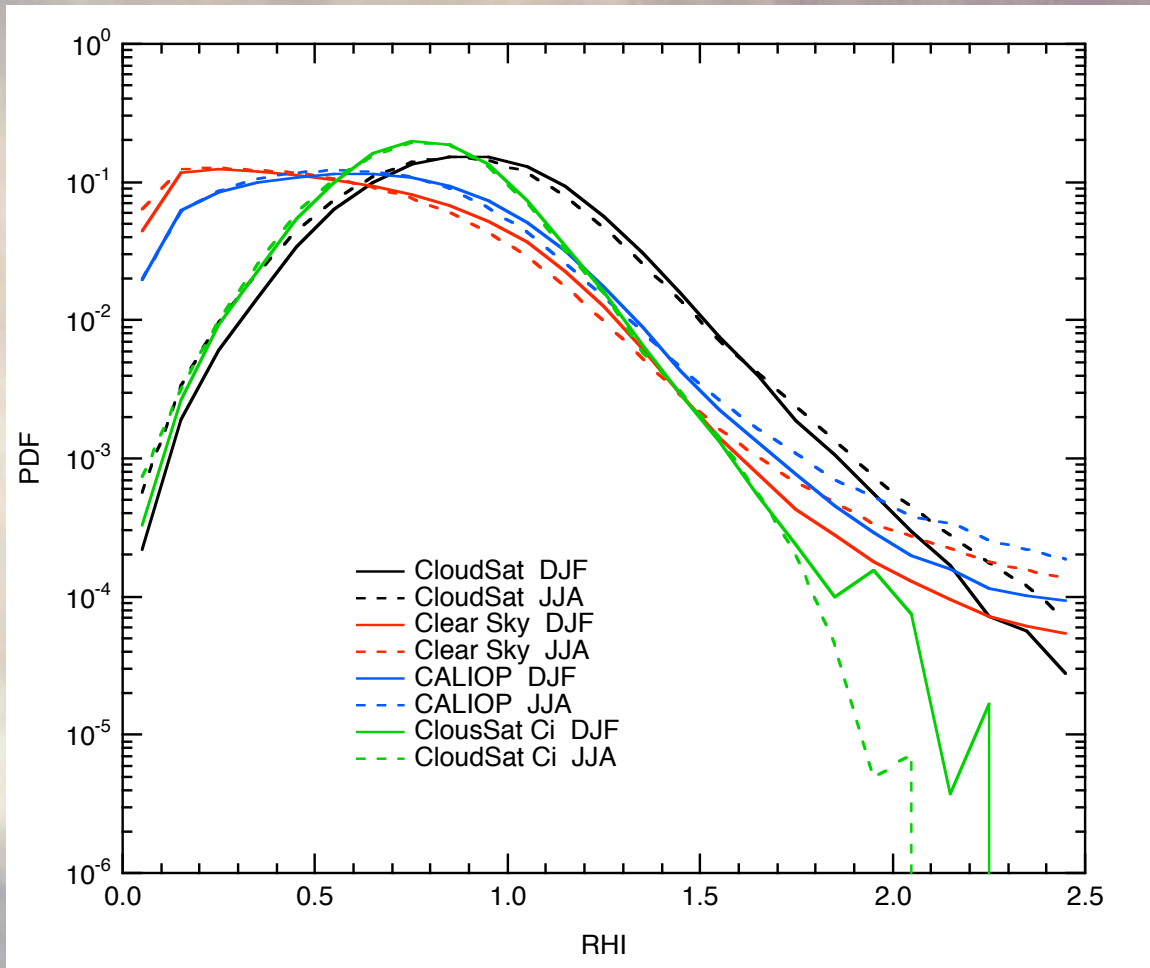
- What are the causes and implications?
 - Nucleation/aerosol differences? Variability in $T(z)$ and $q(z)$?
 - These questions are significant motivators for this work

RHI sampling dependent on cloud type



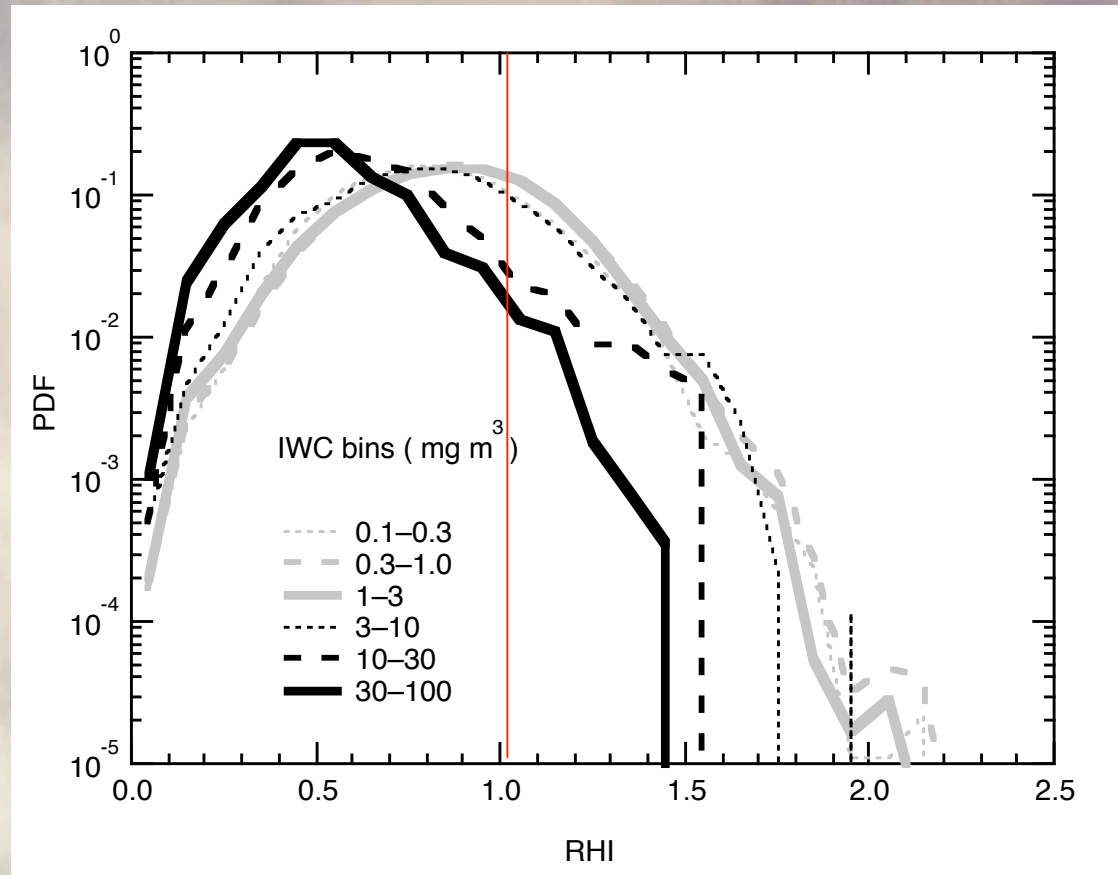
Note: Good quality RHI in presence of thicker clouds could be a consequence of broken cloud scenes: RHI signal most likely from clear/non-opaque spots in Cb, Ns, etc.

In-cloud/clear sky RHi using radar and lidar



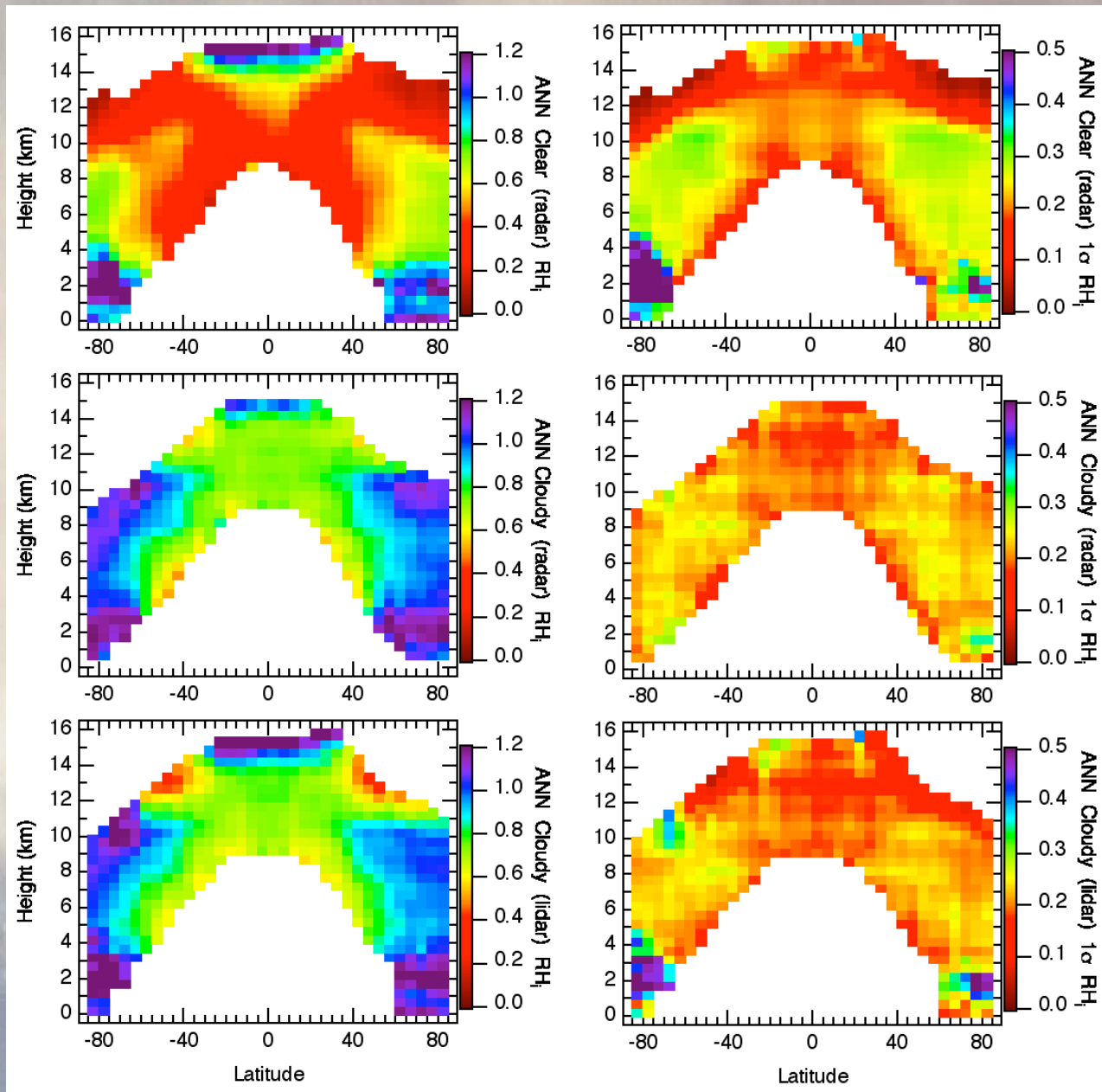
Seasonal, cloud-type, and platform-dependent differences in RHi distributions

RHI & IWC anti-correlated for 5 days of data



- Consistent with some *in situ* aircraft spirals (e.g. MIDCIX campaign)
 - $\sim 25\%$ of Cirrus with $\text{IWC} \leq 1\text{--}10 \text{ mg m}^3$ is supersaturated
- Climate models acutely deficient in these scene types

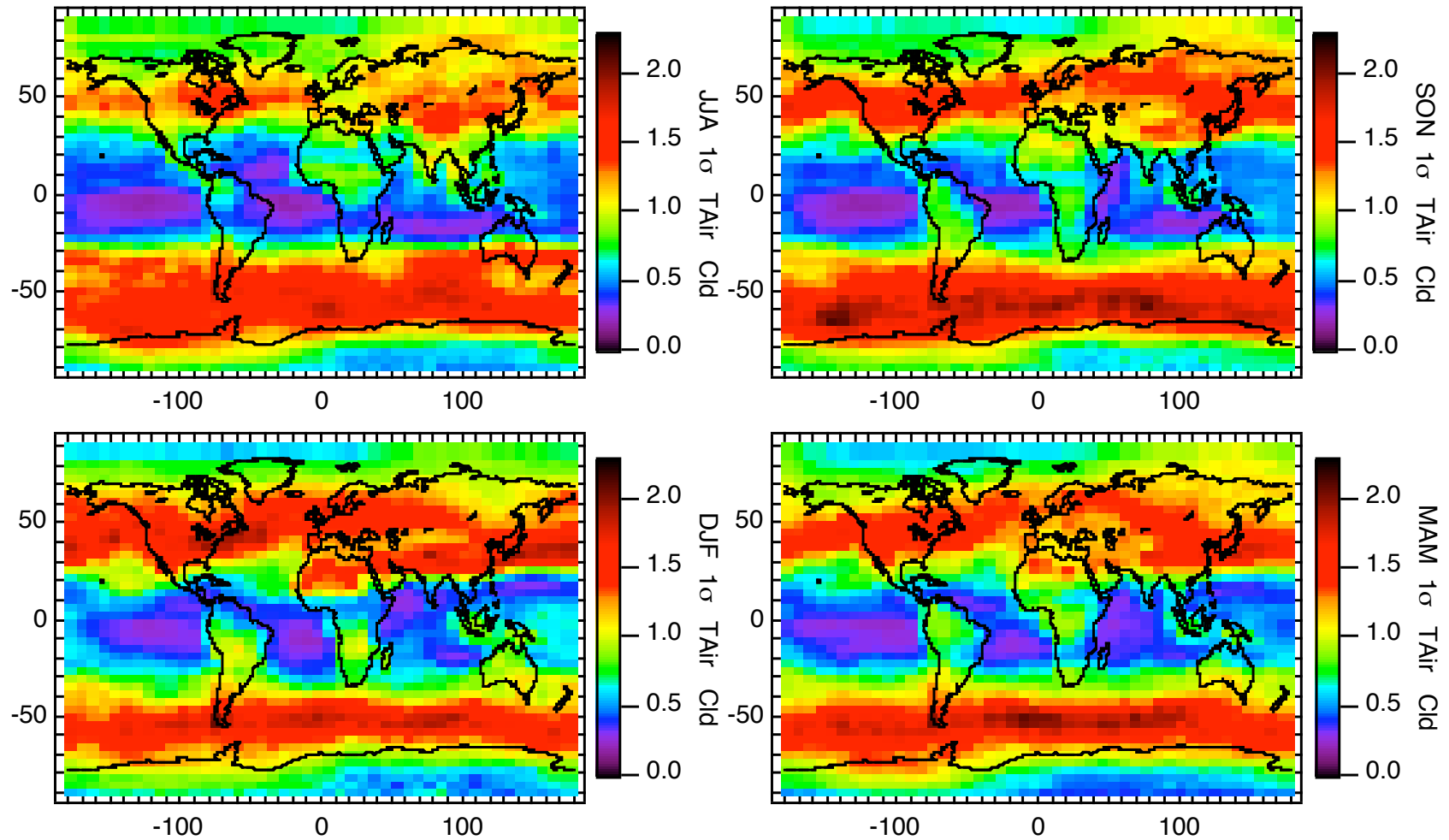
Clear/Cloudy Sky Zonal Mean and Variance of RHI



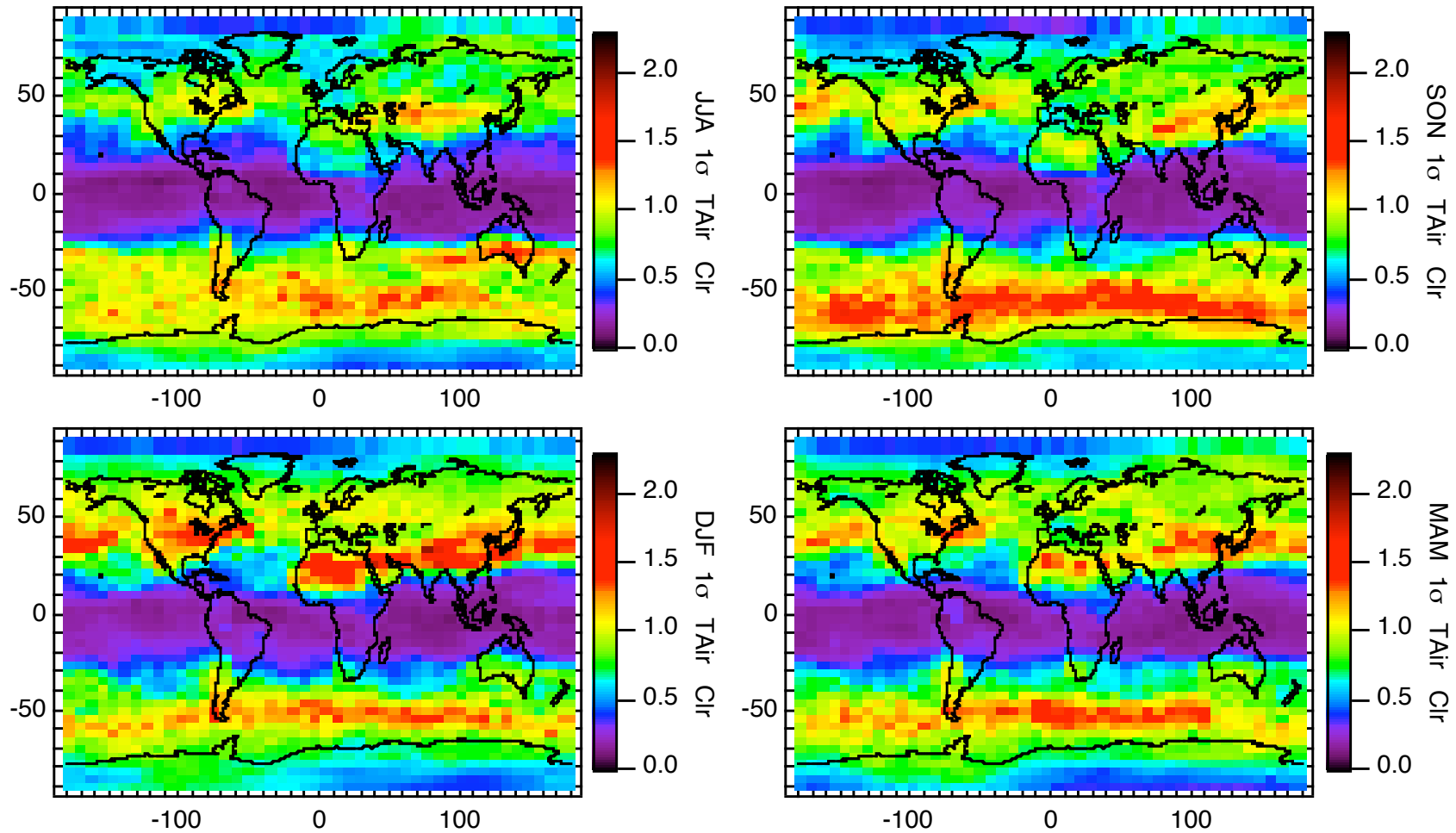
Does T variance control characteristics of RH?

- Clear and cloudy sky AIRS-derived T variance maps
 - Use ECF to partition cloudy/clear sky
 - $ECF \geq 0.05$ for cloudy, $ECF < 0.05$ for clear
- Clear and cloudy T/RH histograms for SH/NH (40–60°)
- Correlations between T variance/average RH

Seasonal cloudy T variance for 150–400 hPa

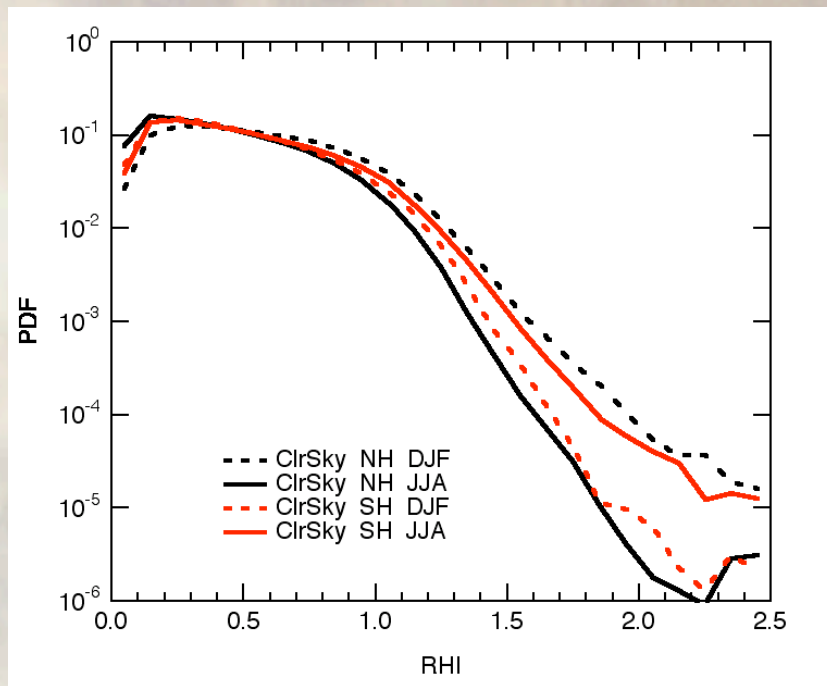


Seasonal clear sky T variance for 150–400 hPa

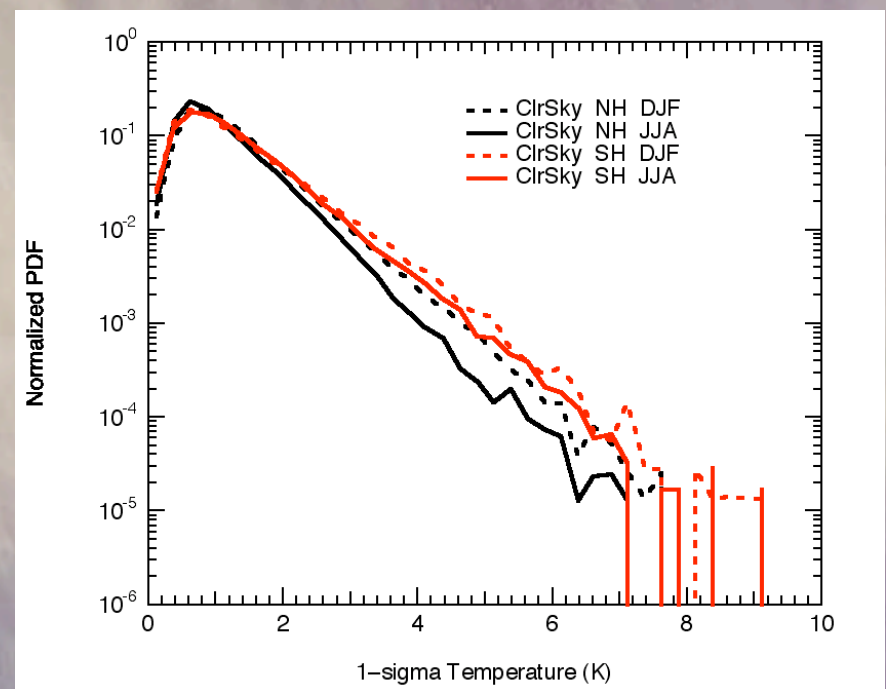


Hemispheric & seasonal variability in clear sky

Clear Sky RHI



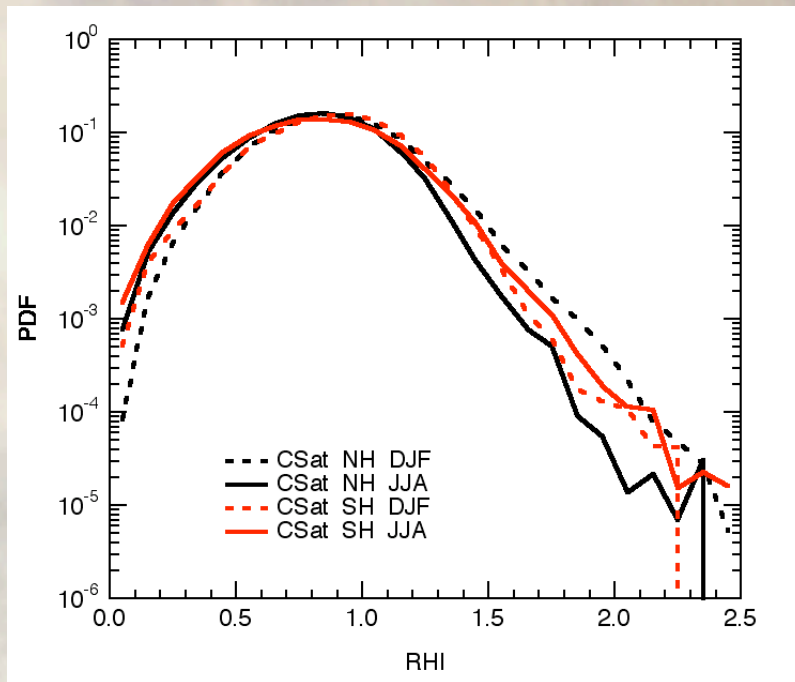
Clear Sky T variance



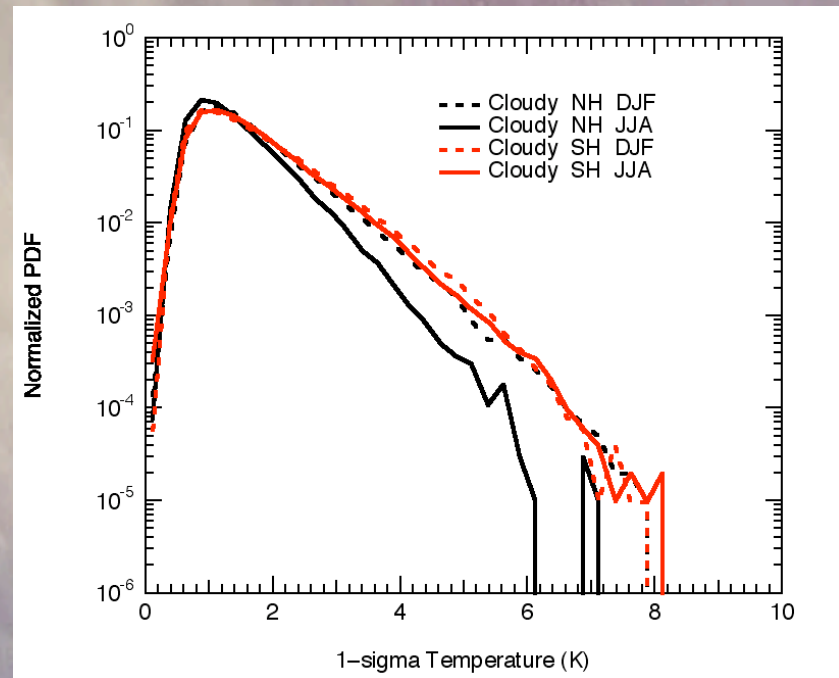
- Strong seasonal cycle in clear sky RHI → winter = higher RHI
- Variance in RHI and T similar in NH → T control on RHI distribution
- Not the case in the SH!

Hemispheric & seasonal variability in cloudy sky

Cldy Sky RHI

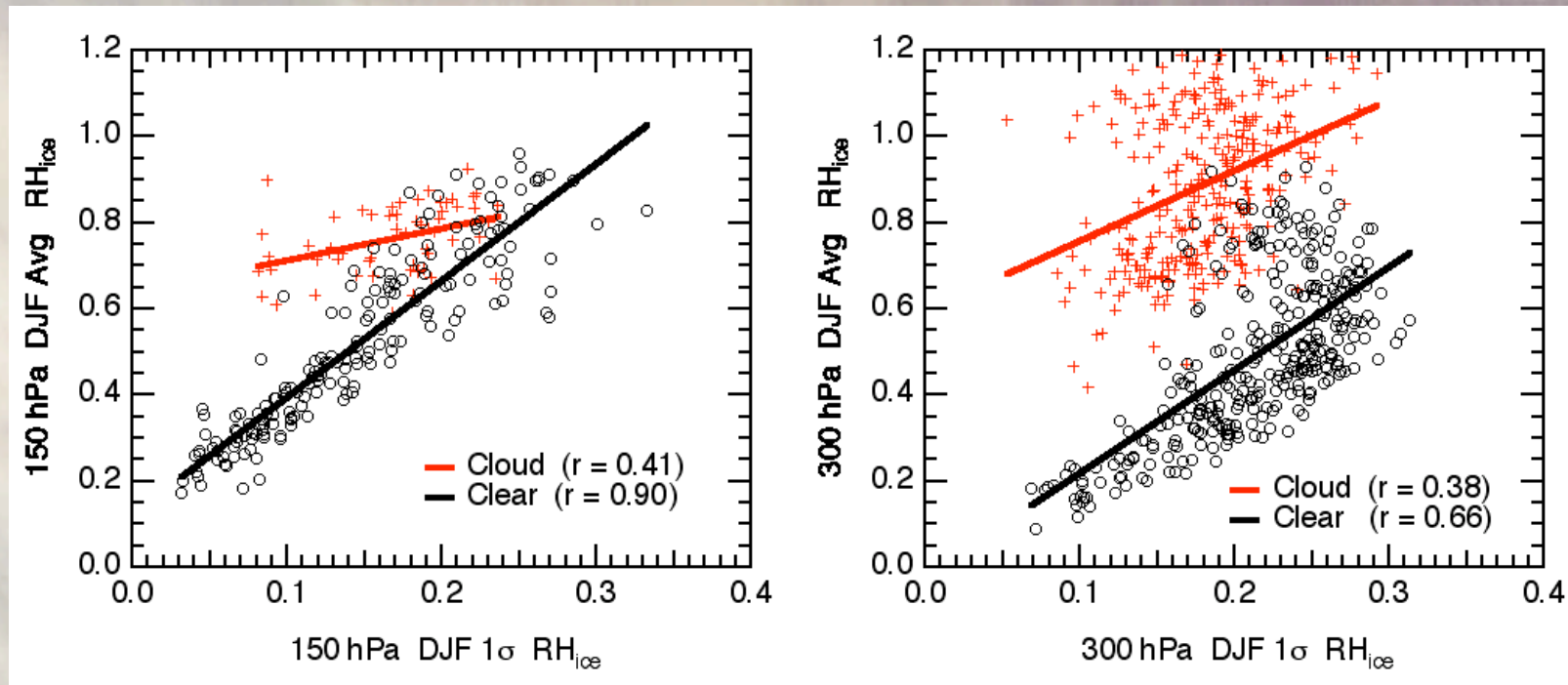


Cldy Sky T variance



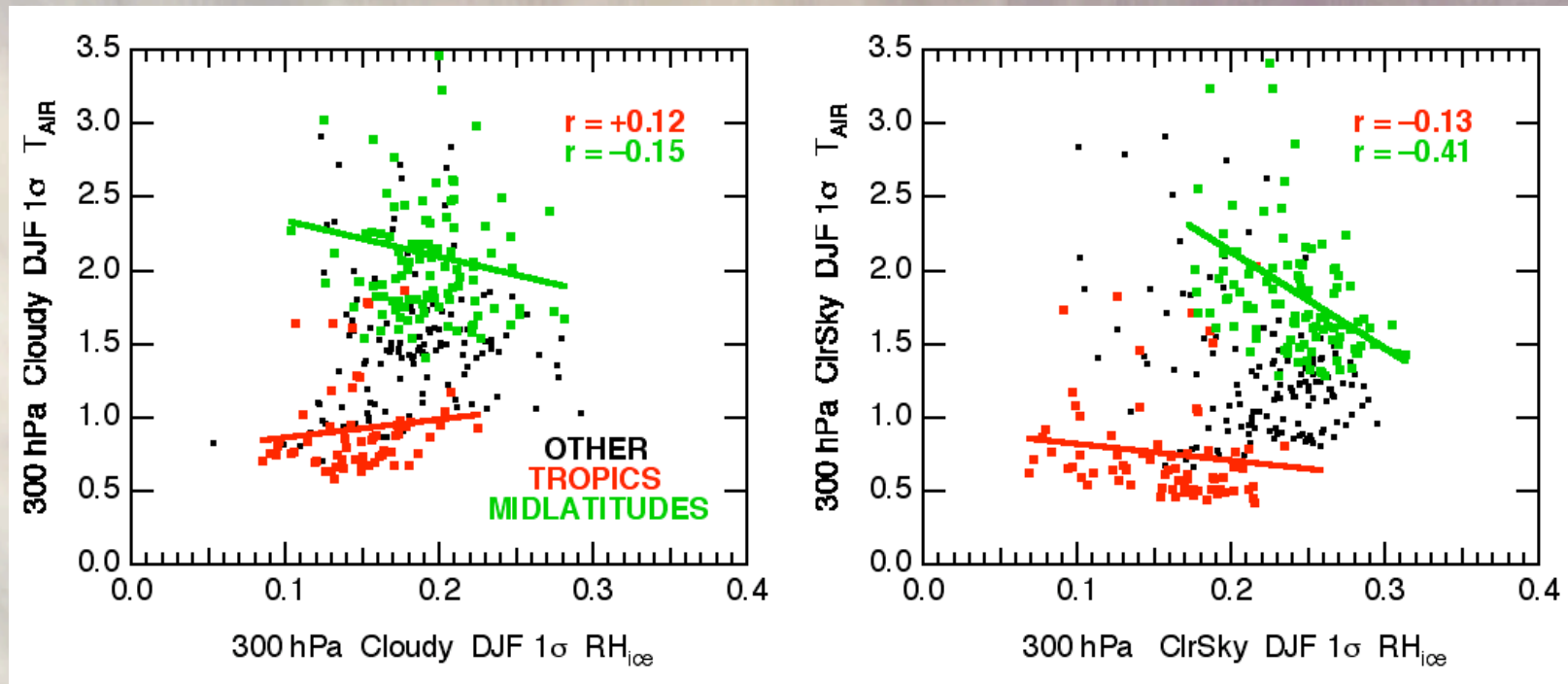
- Somewhat weaker seasonal cycle in cloudy sky RHI → winter = higher RHI
- T variance increases in NH winter → T controls RHI distribution in NH
- Very small differences in SH → more consistent than clear sky

Inherent limitations with bulk PDFs? Point-by-point correlations.



- Positive correlation between average and variance of RHI at most pressure levels
- Slightly weaker correlations in cloudy sky

RHI and T variance correlations



- Correlations of RHI variance and T variance depend on:
 - Latitude/region
 - Cloud/clear sky differences
 - Pressure level
- Inferences about dynamical moistening/drying processes?

Summary and Outlook

- Cloud-humidity profile synergy with A-train
- Challenges remain in interpreting vertical/horizontal resolutions, spatial scale of water vapor/temperature/cloud features
- Possible to discriminate clear, cloudy, and perhaps a few cloud-type variations of RHI
- Significant seasonal, latitudinal, height, cloud/clear sky dependences of RHI
- RHI seasonality connected (in part) to T variance
 - Implications for inference of cloud nucleation/aerosol effects
- Spatial correlations of RHI and T variance
 - Regional/latitudinal dependence suggest difficulty in interpretation of bulk PDFs
 - Different dynamical regimes may moistening/dry and modulate RHI variance in different manners